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# CRASH RESCUE AND FIRE FIGHTING CONCEPTS FOR EXPEDITIONARY AIRFIELDS

by

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NAVAL AIR SYSTEMS COMMAND



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Crash rescue requirements for Marine Corps V/STOL expeditionary airfields have been developed based on the specific needs and the constraints of minimal logistic burden. Helicopters are determined to be essential for off-base crash rescue, but they are generally too slow to result in life-saving benefits in case of major crash fires. Helicopters are therefore not recommended for involvement with fire fighting. The overall crash rescue concepts for both on-base and off-base situations are summarized.

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## INTRODUCTION

The Crash Rescue and Fire Fighting (CRAFF) requirements for Marine Corps expeditionary airfields for the next decade were analyzed and formulated previously [1]. Because the aircraft to be used during this time period are substantially AV-8A or those of the same class, the operational concepts and characteristics of AV-8A aircraft were used as the bases for the concept formulations.

The Marine Corps CRAFF operation on an expeditionary airfield was considered in two parts in Reference 1: ''runway'' and ''other'' areas. The former is concerned with the areas near the airfield or base easily accessible to ground vehicles and the latter is concerned with the vast areas not covered by the former and is usually distant or inconvenient to reach by ground vehicles. Since an expeditionary airfield is necessarily small, the majority of the aircraft emergencies may well occur elsewhere or, in the ''other'' area category. This situation is especially real during war activities when disabled aircraft are mostly attributable to enemy actions. Heavy use of helicopters in connection with the CRAFF operations is therefore apparent.

Helicopters are the primary vehicles for the logistic support of an expeditionary airfield. Due to the limited resources, the use of helicopters must be carefully planned in order to minimize the unnecessary burdens. The extent to which helicopters should be employed and equipped for CRAFF operations for the ''other'' areas are therefore, evaluated here.

The potential fire hazard is extreme during a crash. From the standpoint of human tolerance to a crash fire environment, minimal rescue time is vital. The human endurance or survival limit should therefore, be used to determine the maximum amount of time the helicopter rescue crew can have in order to effect a successful rescue. This time, when compared with the realistic response time of a given helicopter will then be used to determine the criteria or strategies for carrying out the rescue operation.

In this report, the escape limit of a pilot exposed to a crash fire and the methods of fighting a major crash fire using a helicopter are examined to determine the possible desirable benefits. The proper uses of helicopters for CRAFF operations in the off base areas are then recommended as a result.

For completeness, the over-all CRAFF requirements and concepts developed here and those in Reference 1 for Marine Corps expeditionary airfield applications are summarized in the concluding sections of this report.

ESCAPE LIMIT

During a crash fire, the person inside the aircraft is subjected to an environment of extreme heat, toxic gases, and smoke. ''Escape limit'' or ''escape time'' is the length of time after the start of a major crash fire during which a self-initiated escape is possible. The production of toxic gases and smoke in an aircraft are the results of the heat from a crash fire. Generally speaking, these products of heat appear some time after the start of the fire and can incapacitate a person only after the heat has already taken its effect [2, 3]. Therefore, in establishing the escape time only the damaging effects of heat to the pilot need be considered.

The heating effects to a pilot due to a crash fire vary widely depending upon such factors as the extent of the spill, the amount of thermal protection built in to the aircraft, etc. Thus, the escape times can vary from 7 to 16 seconds for various utility/cargo type helicopters to an average of 135 seconds for passenger/cargo fixed-wing aircraft [2]. To establish the reasonable escape time of an AV-8A aircraft pilot the following general data are considered.

Figure 1 shows the relationship between the minimum skin-melting time of an aircraft and its gross weight [3]. The estimated gross weight of AV-8A is between 12,500 and 17,600 pounds [4]. Thus, by Figure 1, its minimum skin-melting time is about 15 seconds. This is the time when the aircraft skin at some weak locations begins to melt or to burn through.

The air inside the cockpit will be heated during a crash fire. A relationship on the human tolerance to a hot air environment convenient for the present discussions is shown in Figure 2 [5]. A temperature of 390$^{o}$F is the highest known temperature to which a human respiratory system has been exposed without damage. This temperature was chosen also by National Advisory Committee for Aeronautics as a threshold value for comparison of the relative hazards of respiratory and skin injury levels [6]. To use this information, some knowledge of the actual air temperature rise history in the AV-8A cockpit during a crash fire is desirable. Unfortunately, no such data is available and any realistic fire test for this purpose alone is cost prohibitive. In the meantime, the best available data from aircraft of functions and size comparable to AV-8A will be considered.

Figure 3 is a summary of the thermal environment inside the cockpit of an F-86 jet fighter in a simulated crash fire of 2,000-ft$^2$ area and 700 gallons of JP-4 fuel [7]. Since fire fighting was conducted during this test, it is assumed that the data up to the time when the radiation level begins to drop represent the true burning effects. That is, before this time, the fire fighting has not significantly affected the environment of the cockpit. Figure 3 shows that the temperature rise in the cockpit due to a crash fire is fairly slow; and at the end of 20 seconds, the temperature condition there is still reasonably mild.

Radiation is by far the fastest mode to cause injury by heating. The injurious level expressed in terms of the radiation absorption rate versus tolerance time is shown in Figure 4 [8]. Clearly, the injurious

radiation level is much too low compared with that emitted from a fire as given in Figure 3. If 0.2 $Btu/ft^2$-sec is used as the pain threshold [7], Figure 3 shows that the fire can build up to this level in less than 3 seconds. When the data from the left radiometer is considered in connection with Figure 4, at 10 seconds after the fire, the human skin can survive about 13 seconds. Based on this observation, the escape time for an AV-8A pilot will not be much longer than 13 seconds.

Figure 3 shows clearly that radiative heating is much faster than the temperature effects, and this is especially so when no fire fighting is attempted. It is therefore essential to minimize the skin exposures of the pilot. Two approaches are possible: reduction of radiation passing through the canopy and of the bare skin areas. The former can be achieved by making the canopy reflective, and the latter by wearing proper covering such as gloves, face masks, etc.

Aircraft canopy material is practically transparent to heat radiation. Thus, a highly reflective canopy can greatly reduce the radiative heating effects to the pilot, thereby increasing the escape time. Aluminum and gold coverings have been used successfully for fire fighters to shield them from the intense radiation from fires. Therefore, these coverings seem to be plausible methods to reduce the radiation influx to the cockpit. Assuming that only 10% of the radiation from a crash fire can pass through a coated canopy, the radiation level in the cockpit will become quite acceptable (see dotted line in Figure 3) and considerable amount of time will be gained. The practicability of this method must be determined in light of the burn-through time and the visibility impairment of the canopy, however.

Based on the above discussions, the escape time of an AV-8A pilot from a crash fire is around 15 seconds. This figure is consistent with the less than 15-second time objective by the Navy crash crew to open a safe rescue path in a crash fire and the 20-second escape time implied in References 2 and 9. Metalizing the aircraft canopy appears to be a promising possibility to increase the escape time and is, therefore, worthwhile pursuing.

## HELICOPTER-BORNE FIRE FIGHTING

Fire fighting directly from a hovering helicopter has been considered advantageous both from the time-saving and accessibility standpoints. Studies and instructions on this subject have been reported both by the Navy and the Army. The Navy developed FIREFLY I[a] for crash fire fighting directly from a UH-1 helicopter [10,11] and the Army designed CRFSS[b] (crash/rescue fire suppression system) for the same purpose [9]. Both of these systems use foam nozzles mounted on a boom to dispense the fire-fighting agent, and they are controlled by the pilot.

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[a] A 50-gallon AFFF (Aqueous Film Forming Foam) fire extinguishing unit for mounting on the outside of UH-1A/B utility helicopters.

[b] A 50-gallon AFFF unit for mounting inside UH-1H helicopter.

## Approaching Technique

Since the same type of helicopters and dispensing methods are used, the fire-fighting techniques recommended for both FIREFLY I and CRFSS are substantially the same and are summarized below [9, 11].

A crash fire is usually very intense. Because of the large demand of oxygen for combustion and the hot gases produced, a large crash fire is accompanied by the strong updraft of rising hot gases and the indraft of air supply toward the fire. They are potential safety hazards for the helicopter; for example, the helicopter can easily lose its lift in the hot gas plume and drift into the fire. The indraft of a large crash fire can be felt by an approaching helicopter within 40 feet of the fire. Therefore, for helicopter safety, the approach to a fire should be made cross wind and to the upwind side of the fire so that the fire is to the right[c] of the pilot as much as is practicable. The position (see Figure 5) will give the pilot the best view of the rescue crew and is most effective for applying extinguishing agent. In case of emergency such as excessive heat or loss of lift, this position is also the best for making quick escape. The helicopter must not be positioned heading toward the fire because a stalled helicopter tends to fall to a position in front of it instead of vertically down.

The foam pattern is controlled by the helicopter altitude and the nozzle location relative to the rotor. For single rotor helicopters (i.e.,UH-1), the nozzle should be located about the midpoint between the rotor shaft and the rotor tip. Lower altitude will result in more horizontal flow of the foam. The helicopter should be maneuvered into a position approximately 20 feet outside the nearest edge of the fire and the best boom altitude for flat terrain is 12 to 18 feet above the ground. The agent application becomes ineffective at higher than 50 feet above the ground.

For fires located on slopes, it should be approached from its upwind side following the same technique as outlined for flat terrain to cut the path and try to move the helicopter to the uphill side.

## Agent Requirement

Many helicopter-borne fire-fighting tests are reported in References 9 and 11, but the data are inappropriate to deduce the agent requirement suitable for general uses. Recently, a tri-service agency has sponsored a generic helicopter fire-fighting study using the Army UH-1H helicopter and boom arrangement (Figure 5) and circular fires of three sizes. The average data are tabulated below [12]:

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[c] Chosen because the foam nozzle mounting boom is on the right side of the helicopter body.

| No. of Fires | Area ($ft^2$) | Agent Used (gallons) | Agent Density ($gal/ft^2$) | 90% Control Time (seconds) |
|---|---|---|---|---|
| 6 | 942 | 95 | 0.10 | 42 |
| 15 | 1,883 | 170 | 0.09 | 75 |
| 9 | 2,825 | 167 | 0.06 | 76 |

As a comparison of the averages, some fire-truck fire-fighting data (fire size: 83' x 70'; fuel content: 2,500 gallon JP-5) are presented below [13]:

| No. of Fires | Truck | Rescue Path (seconds) | Agent Density ($gal/ft^2$) | 50% Control Time (seconds) |
|---|---|---|---|---|
| 6 | MB5 | 9 | 0.06 | 24 |
| 9 | TAU3 | 22 | 0.06 | 38 |

It is seen that the performance of fire trucks is consistent and for helicopter fire fighting more agent is used for small fires than for large fires. This is likely to be due to the fixed agent losses each time when the system is used. As the fire size is increased, these fixed losses on a per unit area basis becomes less significant. For Navy V/STOL aircraft, the sizes of possible crash fires are relatively small. Thus, the agent requirements will be necessarily large; i.e., 0.1 $gal/ft^2$. Using the fire areas developed in Reference 1, the agent requirements for fighting Navy V/STOL aircraft crash fires are:

| Item | AV-8A | Convair 200A | North American XFV-12 |
|---|---|---|---|
| Fire Area, $ft^2$ | 778 | 1,144 | 806 |
| AFFF Requirements: | | | |
| in gallons | 78 | 114 | 81 |
| in pounds | 652 | 953 | 676 |

The figures tabulated above are for fighting one crash fire by well-trained personnel, on level terrain, with no obstacles in the surrounding areas. In the more realistic situation of rough terrains or with combustible materials and obstacles in the neighoorhood of the crash, the agent requirements can be considerably larger.

## Response Time

Rapid response of the CRAFF crew to a crash fire situation will improve greatly the possibility of a successful rescue. For this discussion, we assume that a dedicated helicopter for CRAFF uses is available and that it is located in the same area as the crash crew. The following important events are considered:

1. Emergency call
2. Helicopter take off
3. Fire fighting
4. Safe rescue path opened

The time between events 1 and 2 depends on the flight readiness of the helicopter. When the helicopter is well warmed up, this time is essentially that for the crew to dress up and board the helicopter and for the preflight readiness check. Thirty seconds is considered reasonable.

The time between events 2 and 3 is variable. This time, however, may be considered in two parts: (1) the time between helicopter takeoff and arrival at some fixed distance from the crash site and (2) the time for the helicopter to then arrive at the crash site from that fixed distance. The former part depends on the knowledge of the exact location of the crash and the distance from the helicopter station and is quite unpredictable. The latter part, however, may be estimated from available data of actual fire tests. The average times based on simulated crash fire tests are given below [9].

| Helicopter Location | Ready for Fire Fighting (seconds) |
|---|---|
| 1,000-foot altitude, 1/4 mile from test pit | 54 |
| Hovering near perimeter of test pit | 31 |

During a recent helicopter exercise at NAS Pt. Mugu witnessed by the author, the time for the hovering helicopter to move in from some 1/4 mile distance was estimated to be 1/2 to 1 minute. Thus, 30 seconds is a very optimistic estimate of a hovering helicopter arriving at the crash site from a short distance away. It is important to note that a crash site is not known until the aircraft hits the ground. Therefore, the actual time between events 2 and 3 can be much longer than 30 seconds.

The time between events 3 and 4 is often called the rescue time. It is the time required for the fire fighters to open a safe rescue path to the crashed aircraft. The average times based on available data are summarized below:

| Description | Fire | No. of Tests | Avg. Rescue Path Time (seconds) |
|---|---|---|---|
| Navy FIREFLY I tested at: | | | |
| 1. MCAS Cherry Point in 1968 (Reference 11) | 200-610 gallons fuel mixtures | 28 | 5 |
| 2. NAS Pensacola in 1968 | 150-400 gallon (fuel unspecified) | 9 | 10 |
| Army CRFSS tested at Ft. Rucker in 1970: | | | |
| 1. Data in Reference 9 | 50-500 gallons JP4, 1,000-5,000 $ft^2$ | 57 | 7-13 |
| 2. Data in Reference 9, Appendix I | 50-200 gallons JP4 | 10 | 31 |

Although a large number of fire tests has been reported, it was impossible to make objective comparisons due to the lack of adequate descriptions of the test fires. The discrepancy of the above data could result from many factors. It is reasonable to assume, however, that most of this discrepancy is due to the amount of training and experience of the crew. Since a realistic crash fire situation can be quite different in every respect than these test fires, the actual rescue-path time can be much longer than the above figures even with a well-trained crew.

To summarize, minimal response can be achieved by tailing the disabled aircraft with a CRAFF helicopter. The helicopter then moves into an advantageous position for fire fighting as soon as the aircraft stops on the ground. In this manner, the minimum total response time will be 41 seconds (31 seconds for approaching and 10 seconds for opening a safe rescue path). Comparing with the 15- to 20-second escape limit discussed earlier, this response time is too slow to realize a lifesaving benefit.

## Training

Precise timing and perfect coordination are essential for fighting a crash fire. Some minimum training time information is given in Reference 9 for using the Army CRFSS. This includes, 3 hours of lecture, eight equipment practicing exercises, and three simulated missions using 200-gallon fuel fires. A minimum of one practice fire per month for proficiency maintenance is also specified. With a dedicated helicopter and crew, this amount of training appears to be nominal.

## Summary

Whenever fire fighting directly from a helicopter is considered essential, the crash-fire conditions must be severe enough so that time gain is vital. Data show that even at the minimum time response, such fire-fighting effort can be quite futile, i.e., the life-saving potential is highly questionable. Therefore, helicopter-borne fire-fighting capability will place a severe limitation on the helicopter payload capacity for carrying the more useful rescue crew and the usually much lighter equipment.

In an AV-8A expeditionary airfield, resources are often quite limited. To have a dedicated CRAFF helicopter may well be practically impossible. The discussions presented above give the rationale for not using helicopters for fighting major crash fires. This relieves the available helicopters from the unnecessary burdens of fighting major crash fires, a conclusion consistent with the recommendation that the Army CRFSS has no life-saving potential [9].

## FIRE FIGHTING WITH AIRLIFT EXTINGUISHER

FSK (fire suppression kit) is an 83.5-gallon capacity, airliftable foam extinguisher developed by the Air Force [1, 14] for fighting crash fires in inaccessible areas. During an emergency call it will be airlifted by an HH-43 helicopter to the near vicinity of the crash site. The fire-fighting and rescue crew either will be lowered to the ground by hoist or will jump off the helicopter after it is landed near the crash site. Fire fighting will then be conducted on the ground.

FSK has been used by the Air Force for Local Base Rescue (LBR) for some years. A recent study showed that the maintenance of LBR capabilities was cost prohibitive in terms of the lives saved, disregarding even the fatal injuries involved. As a result, FSK was discontinued in the Air Force in 1972.

From the standpoint of time response, the use of any airlift units for ground crash fire fighting is necessarily much slower than fighting the fire directly from the helicopter. During a recent crash fire fighting exercise at NAS Pt. Mugu, a spill fire of contaminated fuel was used to simulate a crash condition and a helicopter with the CRAFF crew and an FSK was hovering at some 1/4-mile distance from the fire site. The helicopter was called in after ignition, and the timing of the important events were estimated below:

Helicopter arrived and FSK lowered near fire site: >1/2 min.
Crew landed, ran to FSK, and started to fight fire: 1-1/2 min.

This shows a minimum of two minutes required for the hovering crew to be ready for fire fighting.

It is interesting to note that the FSK developed a malfunction during the exercise making fire fighting impossible. As an alternate plan, the helicopter attempted twice to blow the fire with the rotor

wash, and no significant flame flattening effect was observed. The helicopter had to move away at one time due to excessive heating; and at the other time, it had to pull out immediately because it got into the hot gas plume and loss of lift was experienced.

In summary, using an airlift unit to fight a major crash fire is not satisfactory for expeditionary airfield use. Using helicopter rotor wash alone to flatten a crash fire is not only ineffective, but also can cause serious damages to the helicopter and fatal injuries to the rescue crew.

## REQUIREMENTS

### Off Base Areas

Helicopters are the primary vehicle for crash rescue in off-base areas because they are independent of the terrain and surface transportation conditions. Crashed aircraft are always threatened by high fire danger and crash fires often ensue. In order to perform the rescue operations, fire fighting capabilities are a prerequisite.

Discussions in this report show that, aside from the fire-fighting effectiveness and the payload and training requirements, the realistic time response of a helicopter rescue crew is generally too slow to have any life saving benefits in case of major crash fires. In this light, the major functions for off-base crash rescue operations are discussed below:

1. Fire Fighting. Because of the slow response, fighting a major crash fire should not be attempted by the helicopter crash rescue crew. The crew should, however, carry with them portable fire extinguishers for putting out minor fires or smothering any potentional fire hazards in order to facilitate the rescue. The following extinguishers should be satisfactory:

| Type | Approx. Capacity | Applications |
|---|---|---|
| AFFF (foam) | 5 gal | Small spill fires and general uses |
| PKP (powder) | 20 lb | Engine, tail pipe, tire, wheel, spill, and miscellaneous fires |
| $CO_2$ (gas) | 20 lb | Electrical, compartment, and engine fires. Standard and bayonet discharge nozzles should be equipped |

These fire extinguishers, except perhaps AFFF, are common items that are normally carried on fire trucks or located in buildings and, therefore, should be quite readily available.

2. Helicopter. The helicopter will be used for transportation only. Therefore, any helicopter on the as-available basis will be satisfactory. Although this helicopter need not be specially equipped,

a hoisting capability will be desirable. This is true especially when the local terrain is unsuitable for safe landing of the helicopter.

Use of rotor wash to assist any rescue operations should be avoided. For the best response, the helicopter unit should be located at the same general area as the crash crew or the fire department. Thus, whenever an emergency arises, the crew can pick up their gear, board the helicopter, and take off for the rescue.

3. Crash Rescue. The minimum crew for this operation should consist of one rescuer, one fire fighter, and one medic. Personnel for the on-base CRAFF operations will respond to such situations. That is, in case of off-base emergencies, the on-base crash crew will be airlifted to the crash site to carry out the rescue operations. Standard rescue tools and equipment as described in Reference 15 will be required in addition to the hand fire extinguishers. Since the same CRAFF crew will handle both the on-base and off-base rescue operations, the members must be trained to use the available helicopter descent devices (e.g., hoist or sky-genie).

In summary, when an off-base emergency arise, a helicopter with the CRAFF crew from the normal on-base operations will be dispatched. This unit will attempt the rescue operations for all situations unless there is a major crash fire. There will be no special requirement of the crash crew other than the ability to use helicopter descent devices and the standard gear specified for the on-base CRAFF operation.

## Aircraft Improvement

The temperature rise of the cabin air is caused by the heat conducted through the airplane structures and by the interior objects exposed to the radiation of the fire through the practically transparent canopy material. A reflective canopy will greatly reduce the air temperature rise in the cabin. Assuming that the canopy is reflective and has a transmissivity of 0.1, the left radiometer (Figure 3) will indicate a radiative heat flux of 0.2 Btu/ft$^2$-sec (pain threshold) at the end of 25 seconds and the air temperature at the time will be approximately 110$^o$F, a reasonably comfortable environment.

Gain in pilot escape time may be achieved by making the canopy highly reflective. The gold or aluminum coated face shields for fire fighters are appropriate examples. The infrared reflectivity of gold-coated face shield is generally greater than 90% (i.e., <10% heat radiation transmission) for 20% light transmission. Greater light transmission can be obtained by sacrificing the reflectivity. The feasibility of coating aircraft canopies with reflective material must be carefully evaluated based on: pilot visibility, practical gain in pilot escape time, possible additional maintenance requirements, and cost. It must be noted that a reflective canopy will generally increase the pilot's escape time, with potential life-saving benefits more likely when a major crash fire occurs in areas where ground fire fighting can be carried out.

## SUMMARY OF RESULTS

The CRAFF requirements for Marine Corps V/STOL expeditionary airfield discussed here and in Reference 1 are summarized in Table 1. The first two parts in Table 1 pertain to actual CRAFF operations and the last part is a possible aircraft modification for lengthening the pilot escape time.

The over-all CRAFF concepts developed are presented pictorially in Figures 6, 7, and 8. The remote-controlled fire-fighting modular unit given in Figure 6 is described schematically in Figures 9 and 10. This modular unit can be dispatched from either the control tower for quick response or from any convenient locations as appropriate. Following are the recommended operational guidelines:

1. Fighting major crash fires may be conducted in the on-base (runway and nearby) areas easily accessible to ground vehicles. A crash vehicle of 150 gal/300 lbs (AFFF/PKP) twin agent capability will be required. The crash crew will also be equipped with an assortment of standard-sized, portable fire extinguishers, crash/rescue tool kits, aluminized fire fighter's suits, and miscellaneous items [15]. For use in off-base areas, these items must be properly harnessed for back carrying.

2. The conventional practice of runway foaming for preparing gear up landing has questionable benefits in addition to being very expensive. In order to reduce the logistic burden, development of a modular type runway sprinkler system is recommended.

3. For rapid response and efficient use of the available manpower, the CRAFF, medic, and helicopter units of the base should be located in the same area. Thus, during an on-base emergency, the crash and medic crews will use their own ground vehicles and equipment to carry out the crash rescue operation; during an off-base emergency, the same crews will bring their equipment and be carried to the crash site by an available helicopter.

4. Based on available fire test data the rescue crew must open a safe rescue path in less than 15 seconds to be of life-saving benefit.

5. The incapacitating factors of a major crash fire are: radiation, temperature, and smoke. Among these, radiation, is by far the fastest. Since radiation is coming through the aircraft canopy, a reflective canopy can greatly reduce the radiation level inside the cockpit thereby increasing the pilot's escape time.

6. Helicopters should be considered as the transportation to carry the crash rescue crew to off-base areas. However, its response to a major crash fire in the off-base areas is generally too slow to realize life-saving benefits. Thus, a helicopter crash rescue team should not attempt to fight a major crash fire, and specially equipped helicopter dedicated for crash fire fighting is unjustified. A helicopter, preferably with hoisting devices, on an as-available basis will be satisfactory for the off-base crash rescue operations.

7. A helicopter will be dispatched for all off-base emergencies; but major crash fires will not be fought by the helicopter crash rescue unit, nor will the helicopter rotor wash be used to assist in any fire-fighting effort. Portable fire extinguishers must be carried to the crash site in order to extinguish any minor fires or to smother any potential fire hazards (e.g., a fuel spill).

## CONCLUSIONS

1. The conventional crash rescue and fire-fighting requirements for established airfields are too extensive for Marine Corps V/STOL expeditionary airfields. The requirements developed here are minimal, but are adequate to suit the specific needs of the Marine Corps without sacrificing pilot safety.

2. For rapid response and efficient use of manpower, the CRAFF, medic, and helicopter units of the base should be located in the same area. Since personnel will be drawn from these units to form the crash rescue team, joint operating procedures must be developed locally to suit the specific needs.

3. Helicopters are ineffective for fighting major crash fires because of the long response time, limited fire-fighting effectiveness (it is unsafe to use the helicopter rotor wash to assist fire fighting), low payload capacity, extensive training requirements and unavailability of dedicated helicopters. Nevertheless, helicopters, on the as-available basis, may be required to respond to all off-base emergencies including fire fighting.

## RECOMMENDATIONS

Based on the minimum requirements developed, the following items are considered essential for in-depth investigation or hardware development:

1. Modular runway sprinkler system to substitute for runway foaming.

2. Compact, 150 gal/300 lb (AFFF/PKP) capacity, crash vehicle for fighting major crash fires of the V/STOL type aircraft.

3. Reflective canopy to increase time available for the pilot to escape.

4. Remotely controlled fire-fighting module to serve as a first-aid item or to substitute for firemen when extreme danger is involved.

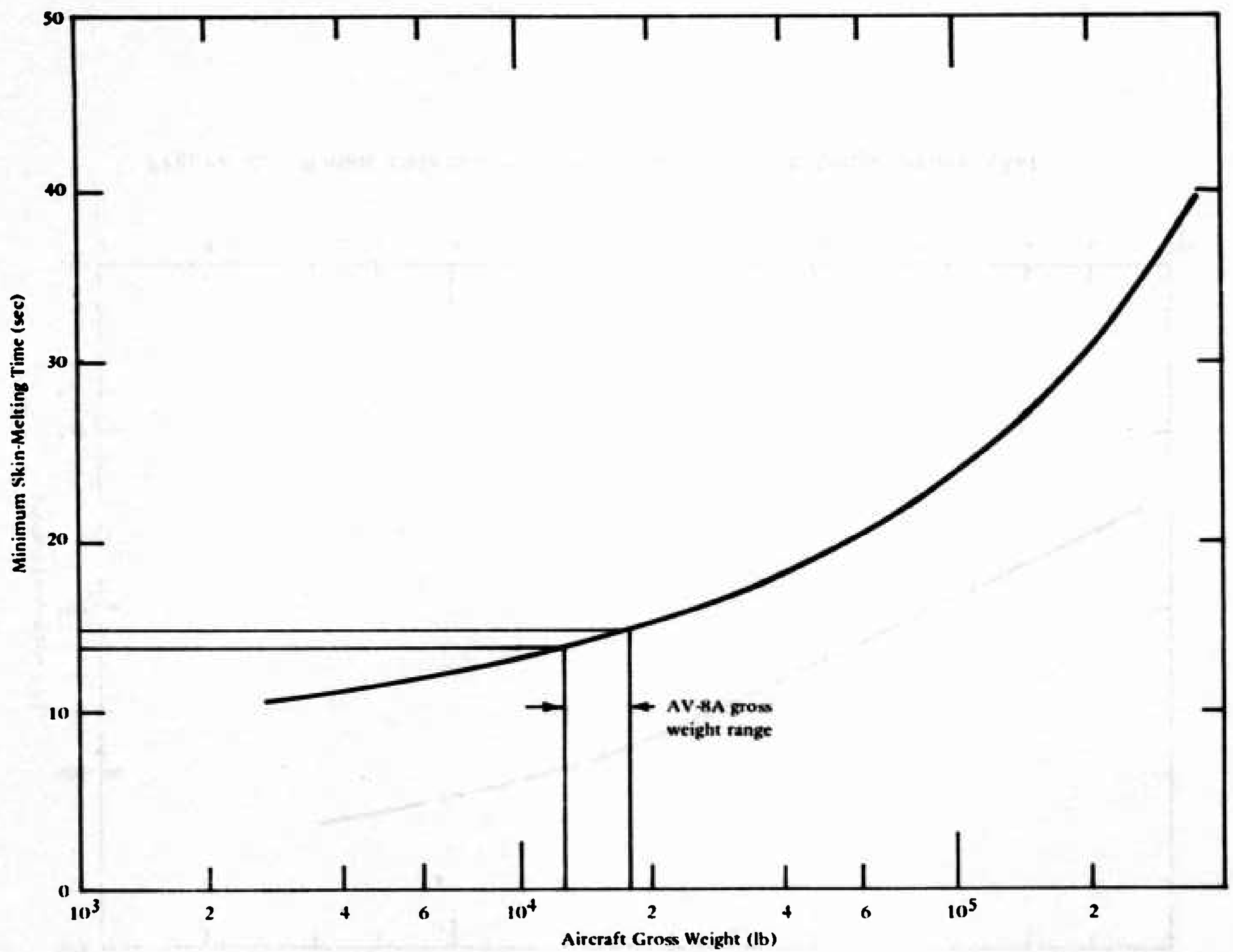



Figure 1. Aircraft minimum skin-melting time (Ref. 3).

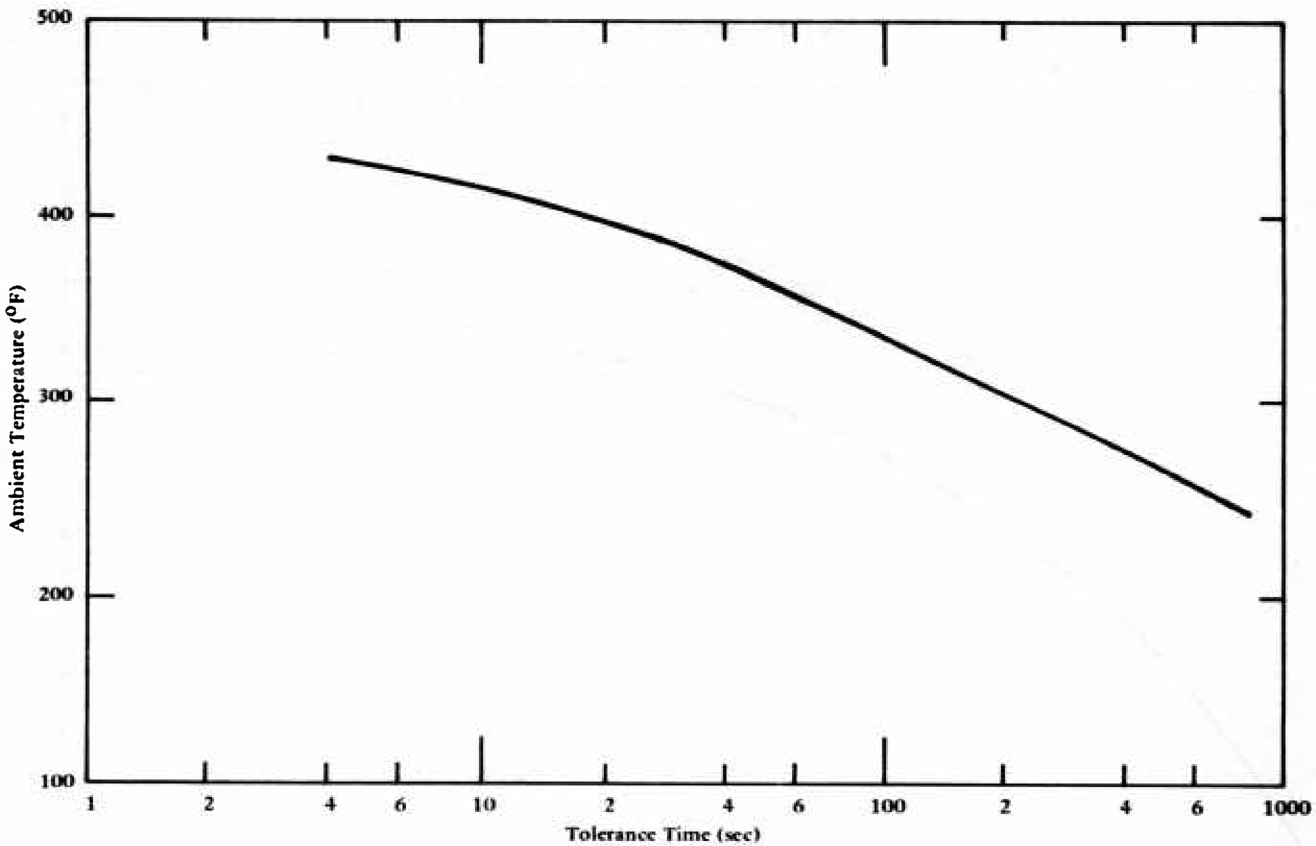



Figure 2. Human tolerance time to ambient air temperature (Ref. 5).

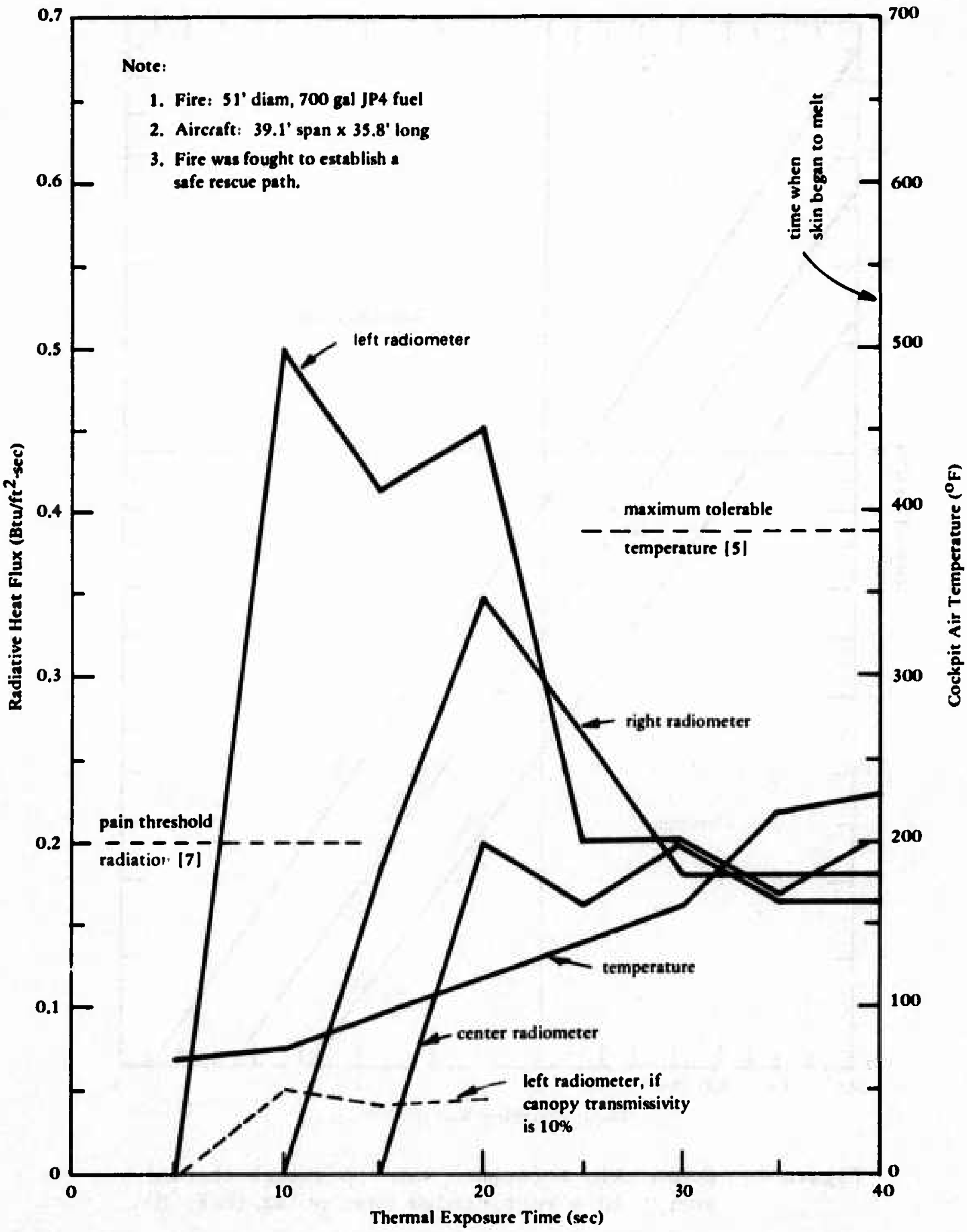



Figure 3. Thermal environment inside cockpit of an F-86 aircraft in simulated crash fire (Ref. 7).

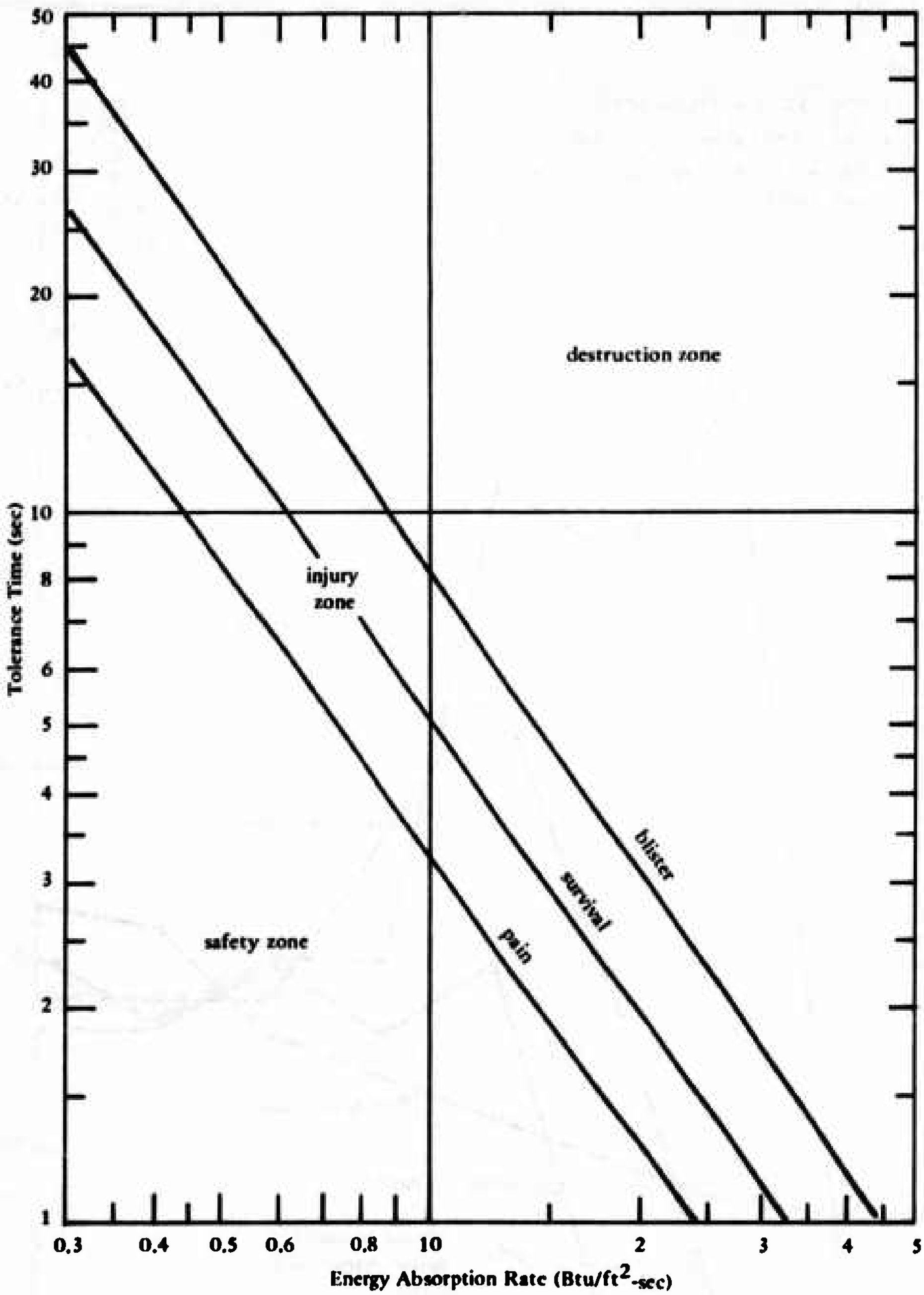



**Figure 4. Human skin tolerance time to absorb thermal energy in a rectangular heat pulse (Ref. 8).**

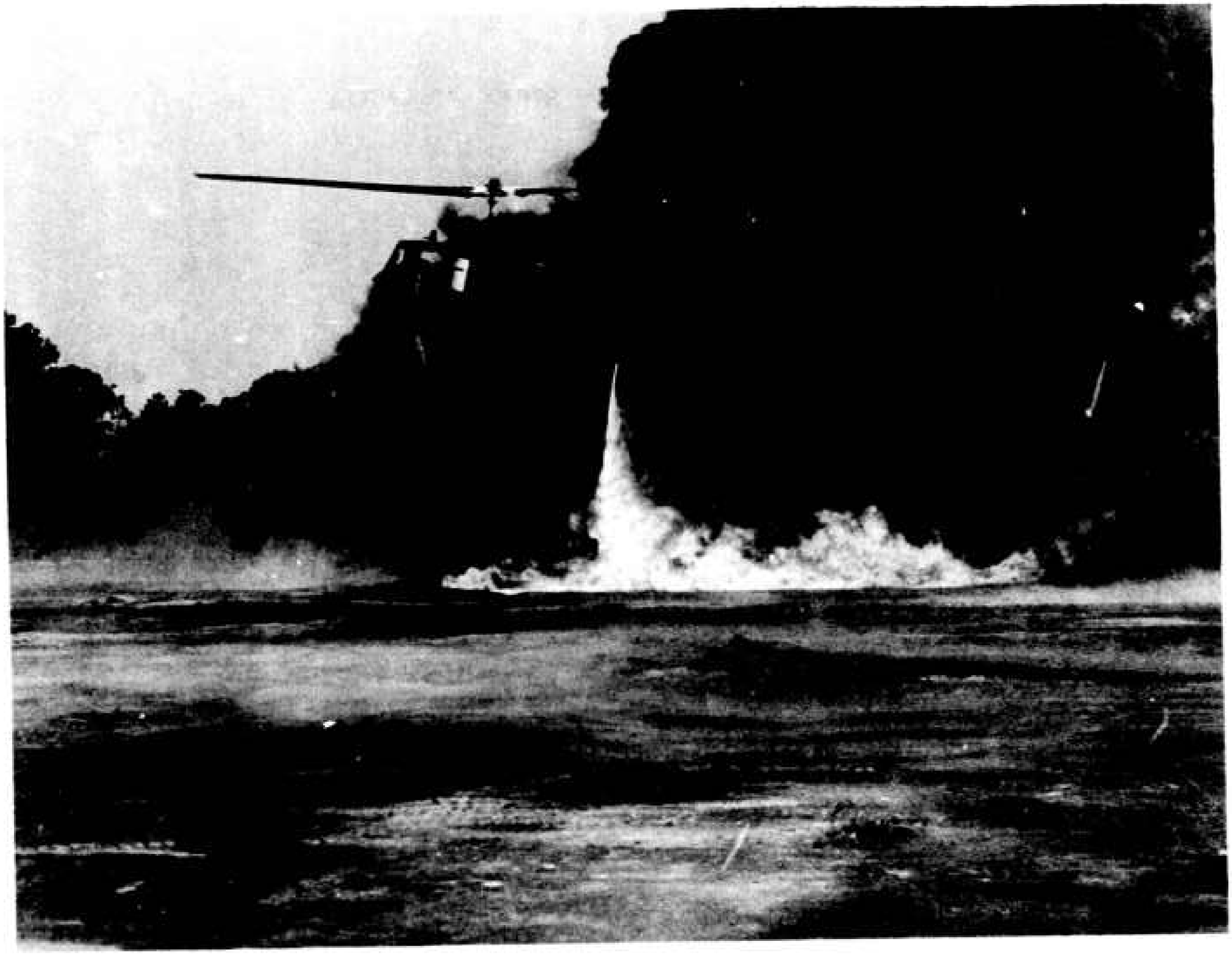


Figure 5. Boom arrangement for the Army helicopter fire fighting tests (Courtesy of Mr. W. J. McNamara, U.S. Army MERDC, Ft. Belvoir, VA.).

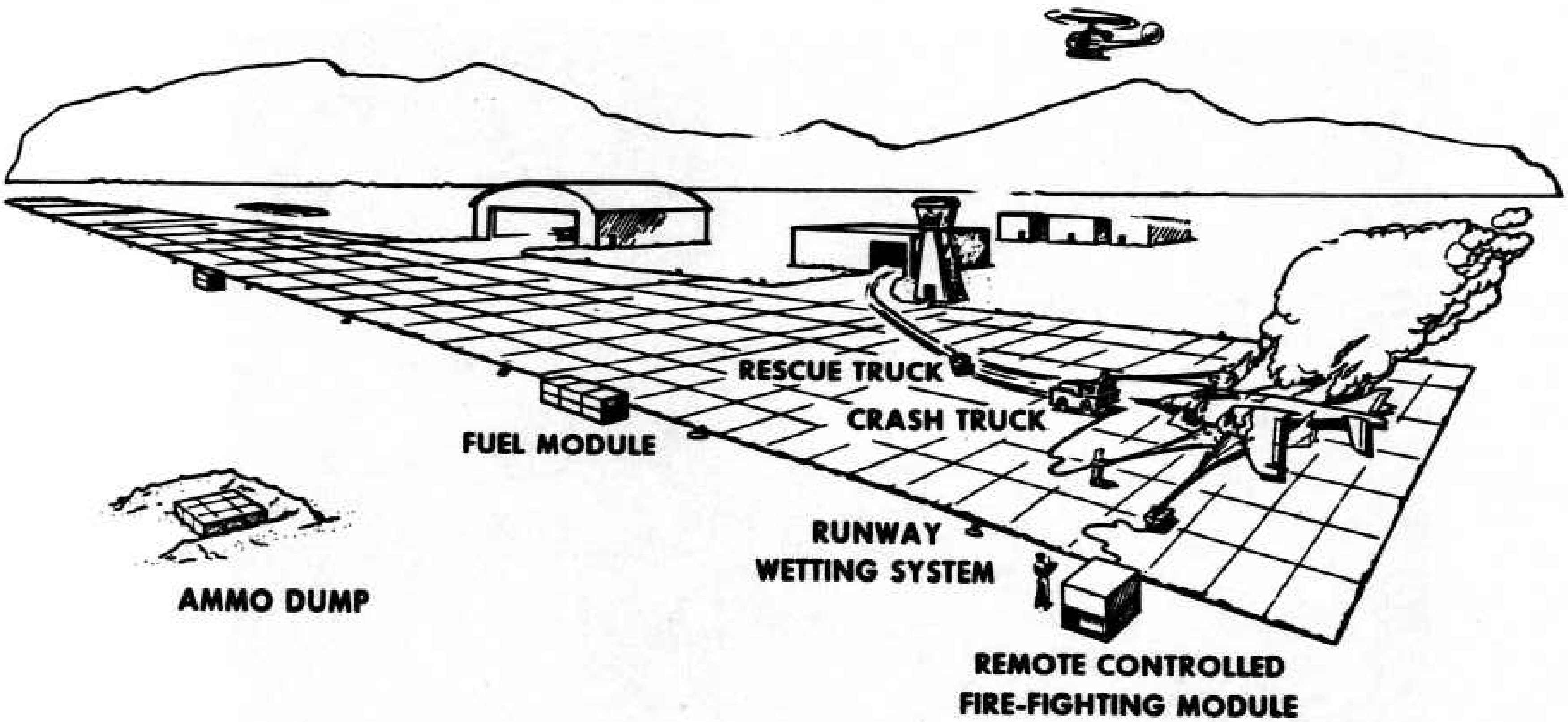



Figure 6. Crash rescue on base.

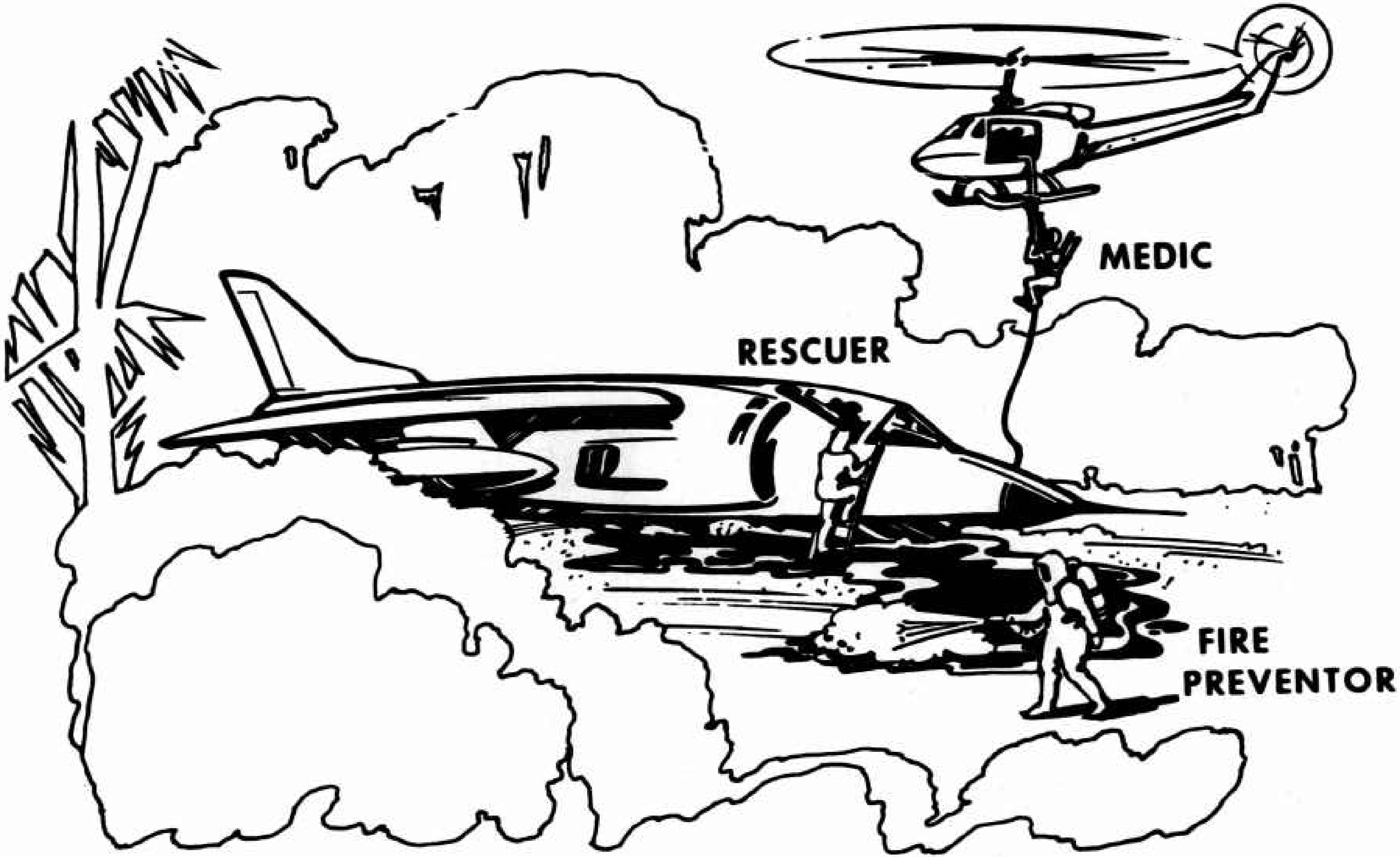
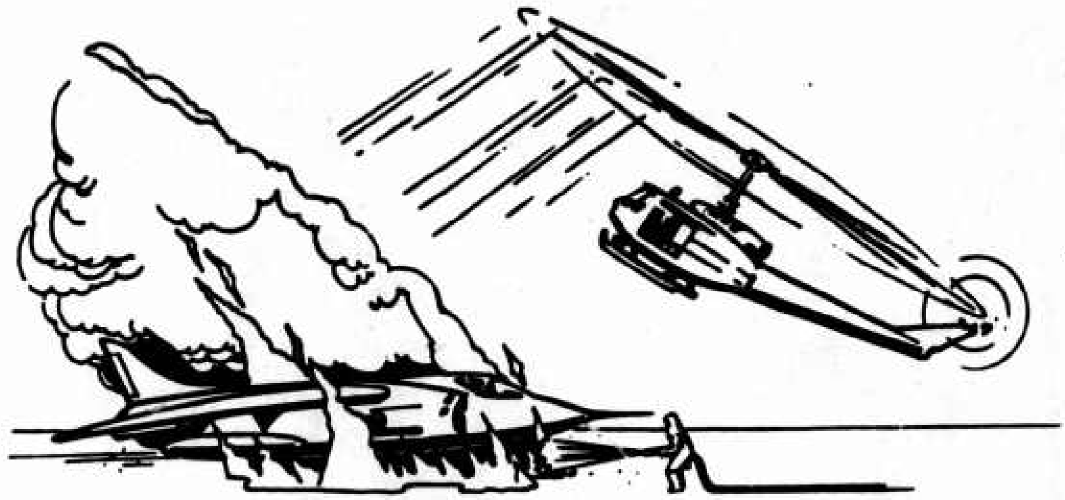



Figure 7. Crash rescue off base.



USE OF ROTOR WASH TO ASSIST FIRE-FIGHTING

USE OF HELICOPTER-MOUNTED FIRE-FIGHTING SYSTEM

Figure 8. Procedures not recommended for crash fire-fighting.

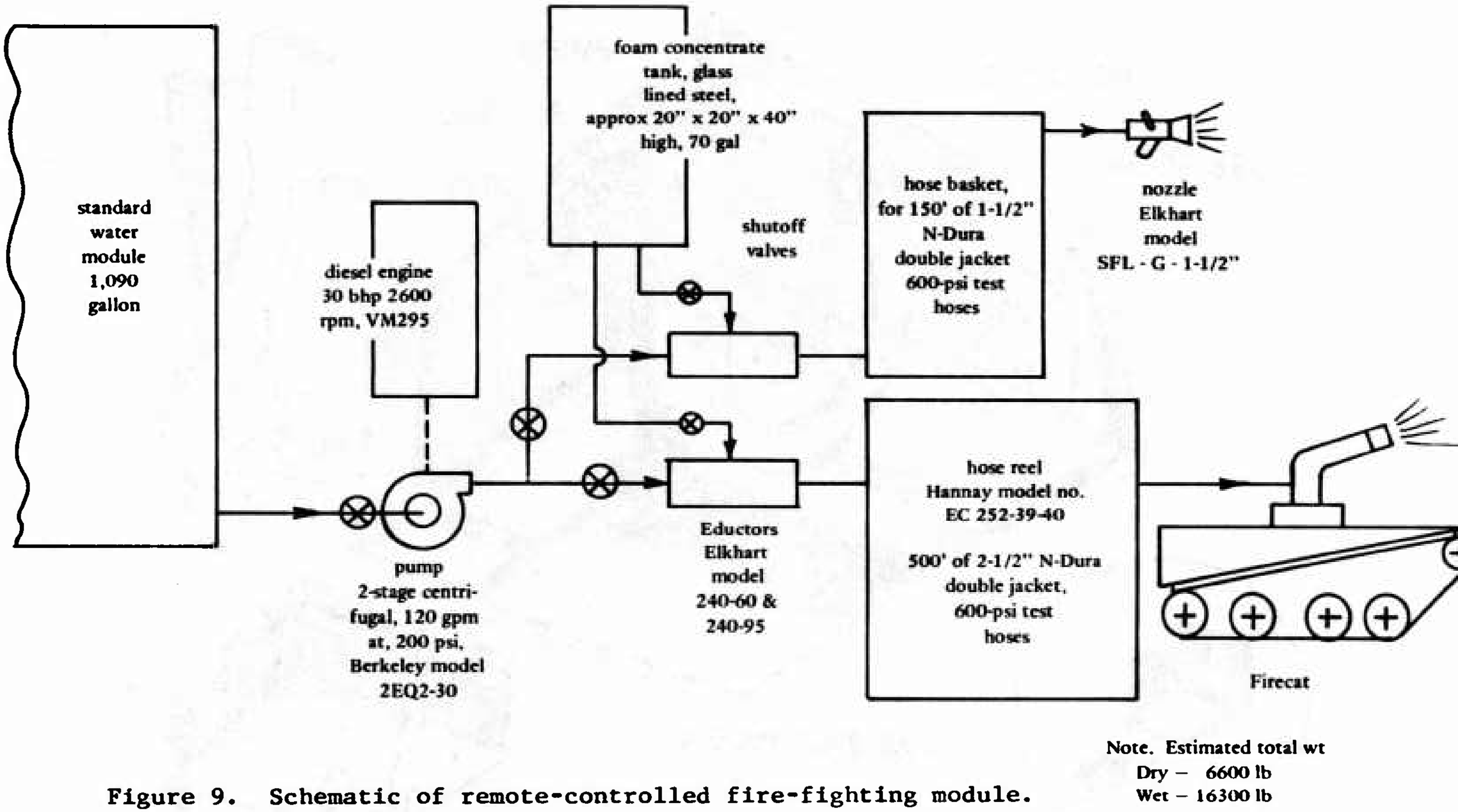



Figure 9. Schematic of remote-controlled fire-fighting module.

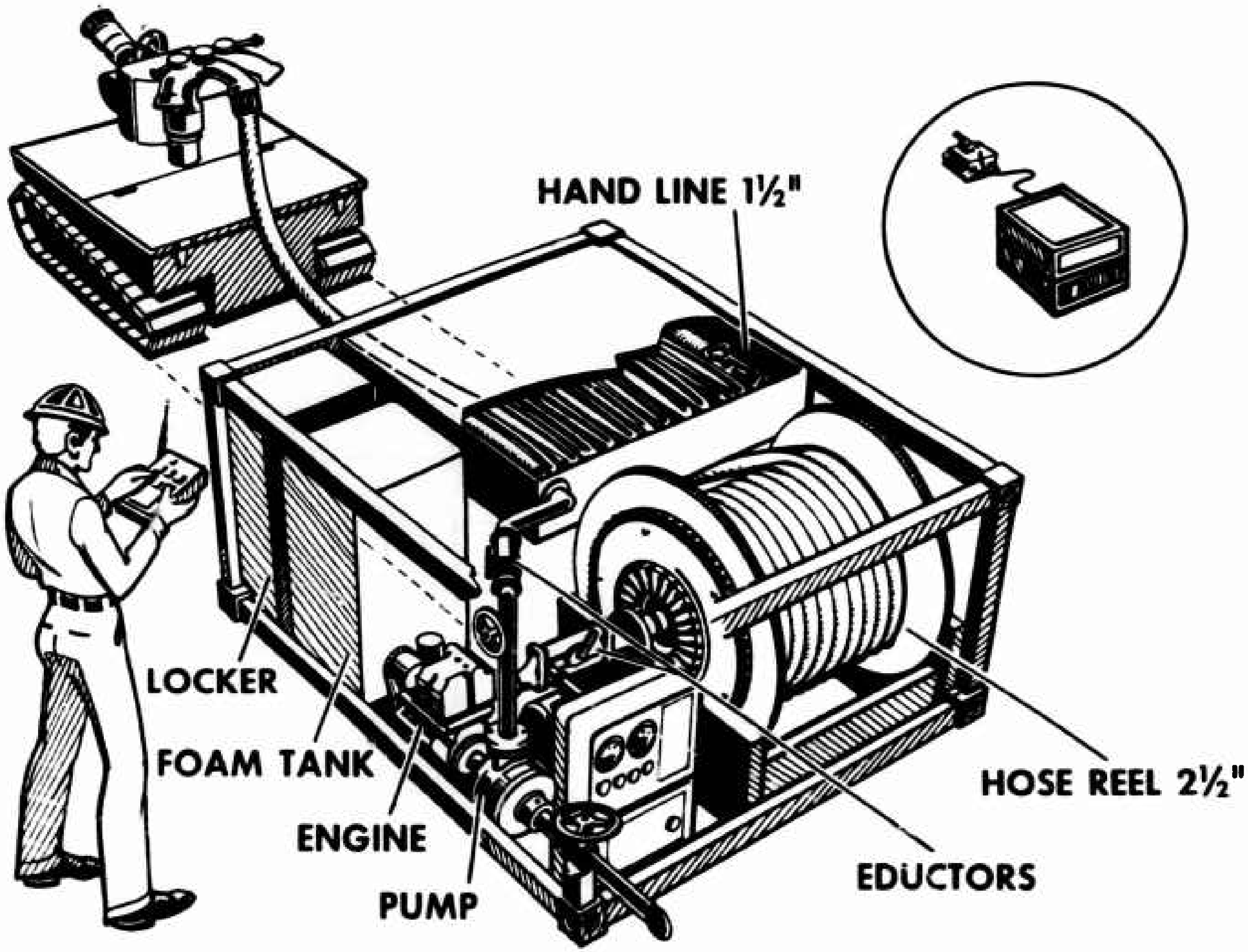



Figure 10. Remote-controlled fire-fighting module.

Table 1. Crash Rescue and Fire-Fighting Requirements for Marine Corps V/STOL Expeditionary Airfields

| Function | Major Equipment | Crew | Remarks |
|---|---|---|---|
| On-Base Areas | | | |
| Fire fighting | 1. 150 gal/300 lb twin agent crash vehicle | 2 | Recommended for development. |
| | 2. Remotely controlled module | 1 | A hose dragging vehicle recommended for T&E in FY 75. |
| Rescue, first aid | Utility truck as available. | 2 | To carry hand extinguishers and rescue gear (Reference 15), first aid items, etc. |
| Runway wetting | Modular runway sprinkler systems. | -- | A substitute for runway foaming. Recommended for development. |
| Off-Base Areas | | | |
| Transportation | Helicopter as available. | As required | From base or nearby helicopter units. |
| Rescue, first aid | Hand extinguishers, rescue gear, first aid items. | 3 | Crew members and items are from the on-base CRAFF personnel. Equipment to be carried on back. |
| Aircraft Improvement | | | |
| Heat radiation shielding | Reflective aircraft canopy. | -- | Recommended for development. |

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